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Community structure of arbuscular mycorrhizal fungi in fluvial and maritime dunes of Brazilian Northeast

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ABSTRACT

Arbuscular mycorrhizal fungi (AMF) are indispensable for the establishment of plant communities, which is essential for the stabilization of sediments in ecosystems, such as sand dunes. This study aimed at assessing the diversity and distribution of AMF in fluvial and maritime dunes, in order to verify if AMF community structure is influenced by physical and chemical soil characteristics. AMF species richness, diversity and community composition, spore density and mycorrhizal colonization were investigated in four natural dunes areas, i.e. two fluvial and two maritime dunes in Bahia State, northeastern Brazil. Soil samples were collected in September 2013 and March 2014. Spore density differed significantly among the dunes and sampling times, with the highest values recorded in the maritime dunes. Fifty-four AMF species were identified in the study areas, of which 51 were identified from field samples and three additional (*Acaulospora longula*,*Acaulospora spinosa* and *Rhizoglomus natalense*) after propagation in trap cultures. The most representative genera were *Acaulospora* (11), *Glomus* (10) and *Gigaspora* (8). *Gigaspora margarita* was the only species found in all areas at both sampling times. The AMF community composition significantly differed among the four dunes. There was a correlation between the AMF community composition and the soil characteristics. Highest species richness per sample was observed in the areas of maritime dunes. The fluvial and maritime dunes of Bahia showed high diversity of AMF and the soil is an important factor in the structure of the AMF community in sand dunes.

1. Introduction

Dunes are sand deposits formed in coastal regions (coastal or maritime dunes), or along river margins and deserts (inland dunes) that can be mobile or fixed, depending on the establishment of vegetation (Giannini et al., 2005). They are fragile and dynamic systems, subjected to natural (erosion) and anthropogenic (mining, tourism) disturbances, which affect the vegetation and physical substrate (Emery and Rudgers, 2010).

In Brazil, the category of plant communities covering dunes is called *restinga* and, having the function of "dune-fixing", it is protected by law (MMA, 2010). Due to the importance of *restingas* for the functional equilibrium of inland and coastal dune environments, it is important to elaborate management strategies that promote the maintenance of important stabilizing plant communities in these environments.

As key components of soil microbiota, arbuscular mycorrhizal fungi (AMF) play an important role in contributing to the maintenance of plant communities (Smith and Read, 2008). The AMF belong to the phylum Glomeromycota, which includes about 270 described species. These fungi are an important link in the soil-plant interface, because they form a mutualistic symbiosis with plant roots of over 80% of vascular plants and act as efficient facilitators for the absorption of nutrients by their host plants, including most inaccessible nutrients (e.g. phosphorous), increase in the complementarity of nutritional resources, ensures greater tolerance to biotic and abiotic stresses, and contribute to the

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stabilization of soils due to the formation of stable soil aggregates (Smith and Read, 2008). These fungi also influence the floristic composition and productivity of ecosystems (van der Heijden et al., 2008).

In dune areas, where environmental conditions are adverse and soils are predominantly sandy and have low nutrient contents, high salinity and low water availability, the arbuscular mycorrhizal symbiosis is an important strategy for plant species to support environmental stresses and be able to develop in these locations (Camprubí et al., 2010). In addition to the role of AMF in the greater availability of nutritional resources, AMF also play a significant role in the stabilization and rehabilitation of dunes. They accomplish this by actively participating in the control of soil erosion through the formation of aggregates, due to the production of glomalin and development of a vast network of hyphae (Aytok et al., 2013; Rillig and Mummey, 2006). The hyphae are also important for water retention and help to stabilize the substrate (Bedini et al., 2009). In these ways, these fungi contribute to the maintenance of habitats and ecological niches of different biological communities.

Knowledge of the AMF diversity present in natural soils is relevant for establishment of conservation strategies *in situ* of these beneficial microorganisms important for the equilibrium of terrestrial environments (Turrini et al., 2010). Given the above, there is a clear need for studies aiming at improving the knowledge of the structure and diversity of AMF communities (Montaño et al., 2012). Such data can be useful for the conservation policies and management of ecosystem processes (Beena et al., 2001).

Several taxonomic and ecological studies on AMF have been carried out in areas of sand dunes and *restingas*: in the USA (Koske and Gemma, 1997), Mexico (Ramos-Zapata et al., 2011), Poland (Błaszkowski et al., 2002), and elsewhere. In Brazil, there have been several studies in areas of maritime dunes (e.g. Silva et al., 2012, 2015; Souza et al., 2012; Stürmer et al., 2013; Stürmer and Bellei, 1994; Trufem et al., 1989, 1994), of which some have contributed to the knowledge of new AMF species (Goto et al., 2011, 2012), but no study of this kind has been carried out in dune areas formed by fluvial influence. Thus, we aimed to determine the diversity, composition and aspects related to the structure of AMF communities, and the mycorrhizal condition of the plant species present in the fluvial and maritime dunes belonging to protected areas in northeastern Brazil. We tested the hypothesis that the AMF diversity is influenced by abiotic factors.

2. Material and methods

2.1. Study areas

Our study sites were four environmental protection areas (EPA) in the state of Bahia, northeastern Brazil, of which two were fluvial dunes ('Lagoa de Itaparica EPA' and 'Dunas e Veredas do Baixo—Médio São Francisco EPA') and the other two maritime dunes ('Lagoas e Dunas do Abaeté EPA' and 'Litoral Norte do Estado da Bahia EPA'). In the following, these four dune areas are shortly called Veredas and Itaparica dunes (of fluvial origin; F) and Litoral Norte and Abaeté (of maritime origin; M) (Table 1).

The Itaparica fluvial dunes are located in the municipality of Xique-Xique, 0.3 km from the Itaparica Lagoon, where, in addition to *caatinga* vegetation, there is a grove of carnauba palms (Table 2; Jacomine et al., 1976). The sampling site of the Veredas dunes is in the municipality of Barra, near the village of Ibiraba, situated at a distance of 1.5 km from the São Francisco River. The vegetation of this area is sparse and open *caatinga*, with a shrubby tree layer and patches of cacti and bromeliads (Table 2; Barreto et al., 1999; Rodarte et al., 2008). In the Abaeté area, the collection site is located 1.3 km from the sea, the vegetation includes herbaceous, shrubby and arboreal plants (Table 2; Britto et al., 1993; Britto and Noblick, 1984). The Litoral Norte dunes are located in the municipality of Mata de São João, at a distance of 1 km from the sea, where the vegetation is composed of herbaceous, shrubby and arboreal species, with typical components of ecosystems associated with Atlantic Forest (Table 2; Dias and Menezes, 2007). The soils of the studied sites were classified as Alisol (Itaparica), Planosol (Veredas) and Arenosol (Abaeté and Litoral Norte) according to FAO (2014).

2.2. Sampling times

Soil samples were collected in September 2013 (corresponding to the end of dry season and start of dry season, in the fluvial and maritime dunes, respectively) and March 2014 (corresponding to the end of rainy season and start of rainy season, in the fluvial and maritime dunes, respectively). Eight plots were delineated in each dune area (with dimensions of 5×20 m), spaced 30 m apart. In each plot a sample was taken (10 sub-samples) of soil and roots in the rhizosphere of the plants at a depth of 0–20 cm, totaling eight composite samples (about 5 kg each) per area. Part of the soil (500 g from each collection point) was sent to the 'Estação Experimental de Cana-de-açúcar do Carpina, da Universidade Federal Rural de Pernambuco (UFRPE)' for chemical and physical analysis, while the remaining soil was used in the experiments and analysis of the AMF parameters.

2.3. Evaluation of root colonization

Fine roots were selected from the soil collected, washed with water, cleared with 10% KOH (25 °C/24 h), and stained with Trypan blue (0.05%) (Phillips and Hayman, 1970). Total mycorrhizal colonization was estimated by the method of McGonigle et al. (1990), with identification of the presence and type of mycorrhizal structures (arbuscules, vesicles or hyphae).

2.4. Extraction of glomerospores and identification of AMF species

The AMF spores and sporocarps were extracted from the samples of 50 g of soil from each collection point, via wet sieving (Gerdemann and Nicolson, 1963). Next, this material underwent

Table 1
Geographic position and climate characteristics of the study areas.

Dune areas	Geographical position	Mean annual Temperature	Mean annual Rainfall	Climate
Fluvial dunes				
Itaparica	11°02′36.69″S–42°47′39.59″W	25.5 °C	562 mm	Semiarid
Veredas	10°47′18.60″S–42°49′17.44″W	26.8 °C	747 mm	Semiarid
Maritime dunes				
Abaeté	12°56′16.56″S–38°20′49.57″W	25 °C	2000 mm	Tropical humid
Litoral Norte	12°27′15.55″S– 37°56′19.05″W	24.6 °C	1680 mm	Tropical humid

Source: Pigozzo et al., 2006; Almeida et al., 2013; Barreto et al., 1999; UFCG, 2014.